



AMERICAN JOURNAL OF ENVIRONMENT AND CLIMATE (AJEC)

ISSN: 2832-403X (ONLINE)

VOLUME 2 ISSUE 3 (2023)



PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

Impact of Climate Change on Water Security and Endorsing Importance of Rainwater Harvesting Technology in Nepal

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Article Information

Received: May 07, 2023

Accepted: July 28, 2023

Published: September 06, 2023

Keywords

*Agriculture, Climate Change,
Forestry, Glaciers, Runoff,
Water Resources*

ABSTRACT

The day-by-day increment in the concentration of greenhouse gases (GHGs) in the atmosphere is widely believed to be a main contributing factor for climate change. It affects widely on diverse sectors such as water resources, agriculture, forestry, human health, biodiversity, and snow cover and aquatic life. Nepal is experiencing the adverse impact of climate change; this includes such as a variability in temperature and precipitation, overbank flooding from snow-fed rivers, and variability in available river and stream water quantity. Climate in the Nepal Himalayas is changing faster than the global average. Moreover, the changes in the high-altitudes have been found more pronounced than in the low-altitudes. Since, there is no definite trend that could be found in the annual precipitation records, clear decreasing trends could be seen in annual number of rainy days during the study period of 1971-2000. The glaciers in the Nepal Himalayas are shrinking rapidly and there will be no glaciers left by 2180. An accelerated glacier melt will cause an increase in water availability at the beginning but ultimately a decrease in water availability after the glaciers disappear. This will widen the gap between water supply and demand. Changing climate may further exacerbate the water stress which already happening in Nepal due to the monsoon dominated climate. Climate change (CC) will also further increase the seasonal imbalance- too much of water during rainy season and too less of it during dry seasons. Rainwater harvesting technology has the potential to provide numerous benefits to communities and individuals, particularly in areas where water resources are scarce or unreliable. From the analysis and through our research work it is found that if we can simply install and construct rainwater harvesting technology in our individual household only. It nearly fulfills about 15-25% of our domestic water demand. As in urban and rural area of Nepal still nearly about 50% of water demand is fulfilled by groundwater source which increase to 60-70% in dry season. The projected physical impacts of climate change on water resources would have substantial socioeconomic impacts and consequences for Nepal. The hydropower potential and agricultural production would be seriously affected by global warming. A reduction in agricultural production would be experienced due to water security and have significant impact on the food security and livelihoods of the subsistence farmers, who make the majority of the Nepal's population. As the urgent need for climate change mitigation remains crucial, putting all the necessary resources and institutions in place for future adaptation is indispensable. The Inter-governmental Panel on Climate Change (IPCC) has listed rainwater-harvesting as a key strategy for a planned adaptation in the water sector. The policy statements about rainwater harvesting-based climate change adaptation are currently not being effectively coordinated.

INTRODUCTION

Water is an essential to life on Earth and is also vital for sustainable development. Without access to safe and clean water, humans and other life forms cannot survive. Access to water, safe and clean drinking water is recognized by the United Nations as a basic human right, essential for the realization of all other human rights (UN Water, 2019). Water scarcity and security are becoming increasingly important issues as global demand for water continues to grow and climate change exacerbates existing water challenges. Climate change is leading to melting glaciers and changing river flows, which can affect the availability of water resources for human consumption, agriculture, and industry (UNEP, 2021). Change in precipitation patterns due to climate change can lead to increased competition for water resources, which can exacerbate tensions and conflicts between different users of water.

Nepal is considered one of the top ten countries most vulnerable to climate change. The country is highly dependent on climate-sensitive sectors such as agriculture, forestry, and water resources, which are already being impacted by changing climate patterns (WFP, 2009). The increasing concentration of greenhouse gases in the atmosphere, mainly carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), is widely considered to be the primary cause of climate change. These gases trap heat in the Earth's atmosphere, causing a rise in global temperatures and disrupting the Earth's climate system. The impacts of climate change are widespread and affect various sectors such as water resources, agriculture, forestry, human health, biodiversity, and aquatic life. In Nepal, climate change has resulted in a rise in temperature and changes in precipitation patterns, leading to flooding and droughts in some regions. The country's mountainous

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terrain and dependence on snow-fed rivers also make it vulnerable to the effects of melting glaciers and changing river flows.

Several studies have shown that the climate in the Nepal Himalayas is changing faster than the global average. The long-term hydrological, meteorological, and glaciological data from the region provide evidence of these changes. The average temperature in the Nepal Himalayas has increased by 1.5°C since the 1970s, which is higher than the global average increase of 0.8°C, over the same period (Chaulagain, 2006). The changes in the high-altitudes have been found more pronounced than in the low-altitudes. Although there was no clear trend in the annual rainfall records, there was a clear downward trend in the number of rainy days per year during the study period from 1971 to 2000. The physical and socio-economic impacts of climate change with reference to water resources are also sensitive and critical in the context of Nepal. River runoff, total water availability, Water quality, glacier extent, evapotranspiration and a temperature rise are main governing parameter of water resources due to climate change. This warming trend has led to the melting of glaciers and snow cover in the region, which has significant implications for water resources and hydropower generation in Nepal and downstream countries. The glaciers in the Nepal Himalayas are shrinking rapidly and there will be no glaciers left by 2180. Climate change is likely to exacerbate water stress already occurring in Nepal due to its monsoon-dominated climate. Climate change will exacerbate this seasonal imbalance. That is, there is too much water in the wet season and too little in the dry season. The projected physical impacts of climate change on water resources will have significant socio-economic impacts on Nepal. Hydropower potential and agricultural production will be severely affected. A reduction in agricultural production would have significant impact on the food security and livelihoods of the subsistence farmers, who make the majority of the Nepal's population.

The Intergovernmental Panel on Climate Change (IPCC) has identified rainwater harvesting as a key strategy for planned adaptation in the water sector. Rainwater harvesting helps reduce dependence on groundwater and surface water sources, which can be increasingly stressed by changing rainfall patterns and increased demand (Smit & Pilifosova, 2003). Most relevant policies, strategies, and laws are pre-climate change, do not offer significant value for developing specific climate change adaptation strategies, and are included in almost all policies for rainwater and there is no mechanism to coordinate the actions of policy statements on storage and strategy documents.

Rainwater harvesting is the practice of collecting and storing rainwater for later use, typically for household purposes such as drinking, cooking, and cleaning. The water is collected from rooftops and other hard surfaces such as pavements or driveways and stored in tanks or cisterns. This method of water collection is often used in areas where access to clean and safe water is limited

or expensive. Rainwater harvesting is a sustainable and cost-effective way to supplement water supply and reduce dependence on municipal water sources. It is widely practiced in many parts of the world, including Nepal (ADPC, 2022). Nepal is a mountainous country, with the Himalayas covering much of the northern part of the country. Approximately 86% of the total land area is covered by hills and mountains. Forests covers about 43.4% of the country's land area and agricultural land covers about 24.1%, almost half of the southern flatland of Terai. The average annual precipitation in Nepal varies widely, ranging from less than 200 mm to more than 5000 mm, with an estimated average value of 1830 mm (MoFE, 2019). This variability in rainfall patterns can have a significant impact on agriculture, water availability, and overall economic development in the country.

Objective

General Objectives

To present a water harvesting technology as one of the appropriate solution to mitigate water scarcity due to climate change

Specific Objective

- To find Average Annually Rainfall intensity
- To find the average Quantity of water that can be collected from Household
- To investigate relationship between climate change and annual precipitation pattern
- To analyze the benefits and significance of Rain Water Harvesting Technology (R.W.T)
- To suggest appropriate design for conveyance and storage facility of rainwater harvesting for individual household.

METHODOLOGY

Study Area

Nepal, country of Asia lying along the southern slope of the Himalayan and Mountain ranges. It is a land lock country located between India to the east, south and west and Tibet Autonomous Region of China to the north. It is located in 28°23'50' N and 84°07'32' E with an area of 147,181 km². According to the preliminary report of National census 2078, the population of Nepal has reached 2,91,92,480 and the annual precipitation is spatially variable with some central and northerly pockets of the country receiving more than 3,000 millimeters (mm), the central and southern plains typically receiving 1,500 – 2,000 mm, and some high-altitude areas in the north receiving less than 1,000 mm.

MATERIALS AND METHODS

Although the potential impacts of climate change on water resources have long been recognized long time ago, relatively little research has been done on rainwater harvesting. The principle focus of climate change research with regard to water security and rain water harvesting was to quantify the direct impacts of

changing precipitation patterns due to climate change and to identify the requirement of rain water harvesting to reduce the impact of water security.

For Quantification of Storm water

Rational Method

In our research we have used rational method for the quantity estimation of surface runoff generated from individual household. The rational equation is the simplest method to determine peak discharge from drainage basin runoff. It is not as complex as other method, but is the most common method used for Quantifying storm discharge.

Rational Equation:

$$Q = CIA/360$$

Where:

Q= Peak discharge, Cubic meter per second C = Runoff coefficient

I= Rainfall intensity, mm/hour A = Drainage area, Hectare

Identifying Rainfall Intensity

The rainfall intensity is the depth of water (in mm) received during a shower divided by the duration of the shower (in hours). It is expressed in millimeters of water depth per hour (mm/hour). For our research we take a data of precipitation from 2015-2023 on yearly basis as in inch per year and converted them into mm/hr. We collect secondary data of precipitation from weather spark then we analyze according to our requirement.

Finding the Value of Coefficient of Runoff

The runoff coefficient (C) is a dimensionless coefficient relating the amount of runoff to the amount of precipitation received. It is a larger value for areas with low infiltration and high runoff (pavement, steep gradient),

Table 1: Different Values of C according to the surface material

Surface	Runoff Coefficient
Asphalt	0.70-0.95
Concrete	0.80-0.95
Brick	0.70-0.85
Roofs	0.75-0.95

and lower for permeable, well vegetated areas (forest, flat land).As in our research we have consider RCC frame structure and cement concrete roof so we take a 0.8 or 80% contribution of precipitation to the surface runoff.

Finding Contributing Area or Catchment Area

Contribution area for the surface runoff from the individual household is taken on the basis of trend of land use and on the basis of urban municipality's average area of 1369 square feet (i.e. 4 Ana) and permissible ground coverage between 0.7-0.75.We have taken 70% coverage as a built-up area.

Finding to Total Demand of Water for Particular Area

As in the case of Nepal there is a quite variation in water demand particularly from 45-135 liter per capital per day. Generally in rural area water demand is about 45-65 Lpcd and for urban area it varies from 100-135 lpcd. Here in our research paper we have taken its value as 110 liter per capita per day (lpcd).With the data from central bureau of statics (CBS) we have calculate the total domestic demand of water for single day.

Finding Total Quantity of Water That Would be Collected Through the RWH

We have used rational method for the quantification of water that can be collected from RWH technology for single day to month and annually for Bharatpur, Lalitpur, Pokhara and Kathmandu.

Finding percentage that RWH technology will cover to total domestic water throughout the year On the basis of number of household and area's population we have determined and analyzed total amount of water that can be collected or recharge through the rainwater harvesting and we find its contribution proportion to fulfill total annual domestic demand of particular area.

The study was generally based on secondary data. More than 15 scientific journal articles published in international journals, several reports, few published books and some authorize websites were selected and critically reviewed. Here, syntheses have been drawn after reviewing those papers in order to calculate the rainwater harvesting technology design and water quantity and analysis the impact of climate change in water security of Nepal.

RESULT AND DISCUSSION

Climate change and water security

Climate change and water security are closely linked. As global temperatures rise, precipitation patterns are changing, causing more frequent and severe droughts, floods, and storms. These changes affect the availability, quality, and distribution of freshwater resources, which are essential for human health, agriculture, and industry. The per capita water consumption of the Nepal, 35 to 55 liters per capita per day (LPCD), which is significantly lower than the WHO standard, 112 to 150 LPCD. Climate change impact the resources of water which will directly impact the per capita consumption of water in Nepal. Agricultural sectors, crops, livestock and horticulture largely depend on the water sources mainly precipitation, rivers, ponds and groundwater. Variability in climate and precipitation patterns impact the soil moisture and rise in temperature rapidly increase the evaporation process, increasing the demand of more water. The study of the selected area shows that if rainwater harvesting technology is adapted, water demand can be fulfilled. As the depth of groundwater table from surface is growing, area with high population like Kathmandu, Pokhara, Lalitpur, Bhakatapur, Chitwan, Dharan and Hetauda are not able to fulfill their water supply demand.

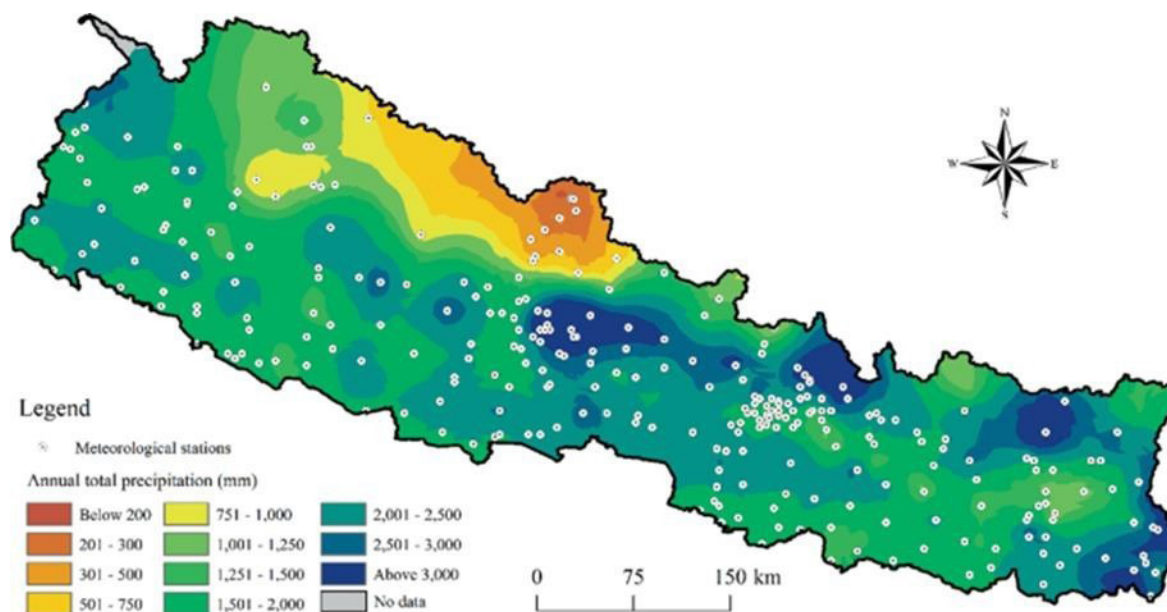


Figure 1: Average Annual Precipitation of Nepal (1985-2021) Source: The soil of Nepal, 2021

Annual Precipitation Distribution

Nepal's climate is highly diverse due to its topography, and it can be classified into five broad climatic zones based on altitude and precipitation patterns. The Terai region, which lies in the southern part of Nepal at less than 500m above sea level has subtropical monsoon climate characterized by high temperature and heavy precipitation during the summer to the high Himalayan region which lies in the northernmost part of Nepal at over 5000m. Average temperatures decline from a peak of over 24°C in the south down to sub- zero temperatures in Nepal's highest mountains. Precipitation is spatially variable with some central and northerly pockets of the country receiving more than 3,000 millimeters (mm), the central and southern plains typically receiving 1,500 – 2,000 mm, and some high-altitude areas in the north receiving less than 1,000 mm.

The northern regions of Nepal receive rainfall from both

the summer monsoon and winter precipitation, which is brought in by the westerly winds. Some areas in the central and northern parts of the country, such as the Pokhara valley, the Kathmandu valley, and the eastern Himalayas, receive high amounts of rainfall, while other areas in the northern highlands receive very little rainfall due to the rain shadow effect caused by the Himalayas.

Precipitation plays a critical role in supporting human well-being and ecosystems, and changes in precipitation patterns can have significant impacts on both. Rainfall and the timing of snow melt and evaporation rate can all affect the amount of surface water and groundwater available for drinking, irrigation, and industry. They also influence river flooding and can determine what types of animals and plants including agricultural crops. Changes in precipitation can disrupt a wide range of natural processes, particularly if these changes occur more quickly than plant and animal species can adapt.

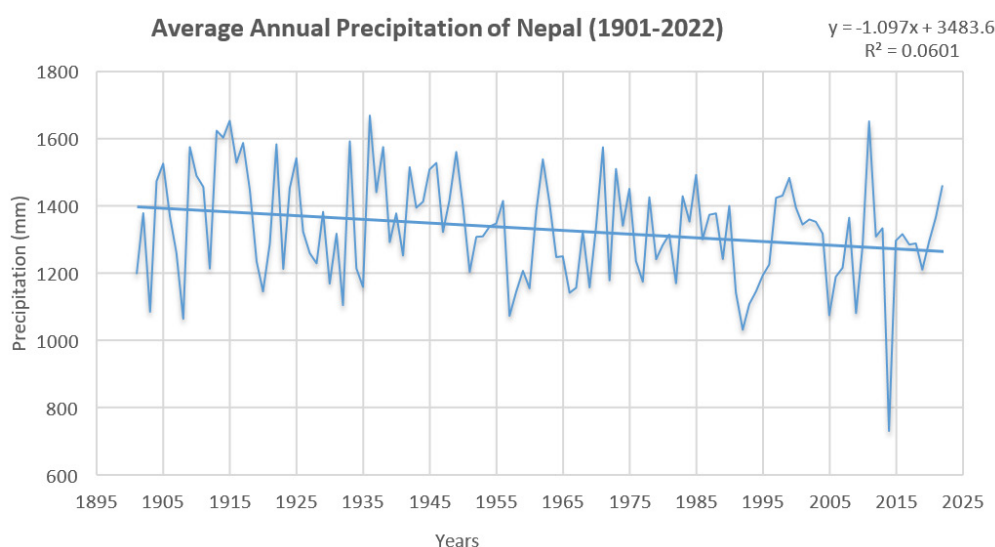


Figure 2: Average Annual Mean Precipitation (mm) of Nepal over the period 1901-2020

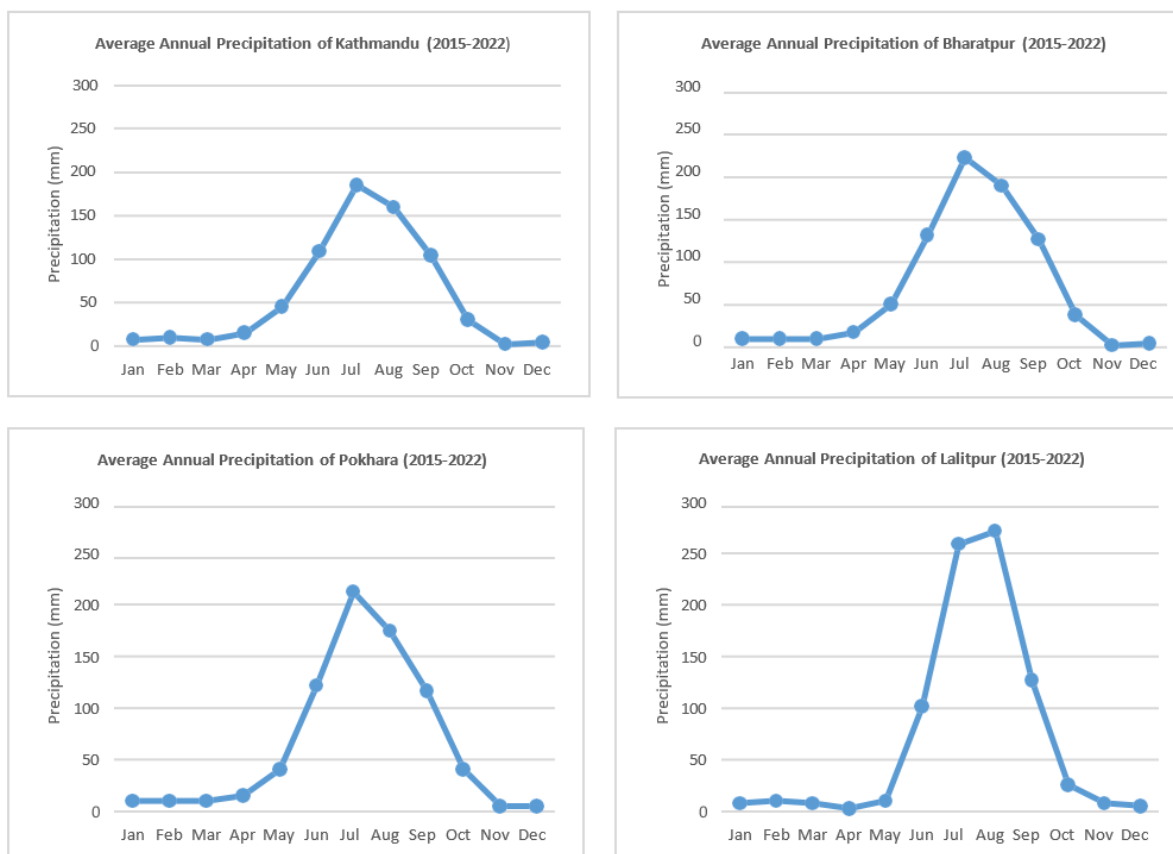


Figure 3: Average monthly precipitation (mm) in Kathmandu, Bharatpur, Pokhara and Lalitpur over the period of 2015-2022

Rainwater Harvesting Technology

Water harvesting is the process of collecting and storing rainwater or other sources of water, such as groundwater or surface water, for later use. The two common rainwater harvesting technologies are surface runoff harvesting and ground recharge.

Surface Runoff Harvesting

This type of rainwater harvesting involves collecting and storing rainwater that runs off from the surface of roofs, roads, and other impermeable surfaces. The water is collected in storage tanks or reservoirs, and can be used for various purposes such as irrigation, livestock, and household use. This technique is relatively simple and cost-effective, but it requires regular maintenance to ensure that the storage tanks are clean and free of debris.

Groundwater Recharge

This type of rainwater harvesting involves storing rainwater underground in order to recharge groundwater reserves. The technique involves capturing rainwater in storage tanks or ponds, and then slowly releasing the water into the ground through recharge wells or infiltration basins. This helps to replenish the groundwater supply and reduce the risk of groundwater depletion. This technique is more complex than surface runoff harvesting and requires careful planning and management to ensure

that the groundwater is being recharged effectively.

Both of these rainwater harvesting technologies have their own advantages and disadvantages, and the choice of which one to use depends on various factors such as the availability of space, local rainfall patterns, and water demand. The characteristics of water harvesting can vary depending on the specific method or system used, some of the general characteristics are collection surface, collection efficiency, storage capacity, water quality, maintenances, sustainability and cost.

Purpose of Rainwater Harvesting Technology

The rainwater harvesting depended upon the technique of water harvesting adapted in the area. The main purpose of rainwater harvesting achieves the water demand of the household, community and society. This can also relief the burden of the government to supply water and to meet the increasing demands. As population is growing, demand of water is increasing, government of Nepal is struggling to provide adequate and reliable water supplies. By introducing rainwater harvesting to the communities, the stress on centralized water system and infrastructure can be reduced.

Design of Rainwater Harvesting

The below drawing is the suggested design after the study and analysis of data.

RainFlo 1100 Gallon Above Ground System		
Item #	Description of System Components	Qty. Supplied with Package
1	Roof Gutters	
2	Downspout	
3	Rain Filter: Leaf Eater Advance	1
4	3 Inch Rain Harvesting First Flush Diverter (See Installation Instructions)	1
5	3" PVC Pipe with Elbows for Rain Water Inlet	Some Included
6	Pipe Gasket	1
7	Grad 1" Stainless Steel Floating Extractor (See Pump Connection Detail)	1
8	Flexible Hose and Bulkhead Fitting for Floating Extractor	1
9	Tank Overflow Outlet	1
10	Bulkhead Fitting and Plug Pre-Installed in Tank	2
11	16" Tank Access Lid with Vent	1
12	Compacted Soil, Gravel or Concrete for Tank Base	
13	RainFlo MHP75A Pump	1
14	Pump Power Cord, Requires 115 volt Power Supply	
15	1" Schedule 40 PVC Pipe and Adapters for Discharge to Use Point (Not Supplied)	
16	Pump Cover	1
17	Tank Level Gauge (See installation Instructions Included with Gauge)	1
18	Norwesco 1100 Gallon Polyethylene Tank	1

NOTE #1: Pump should be located within close proximity to the tank.

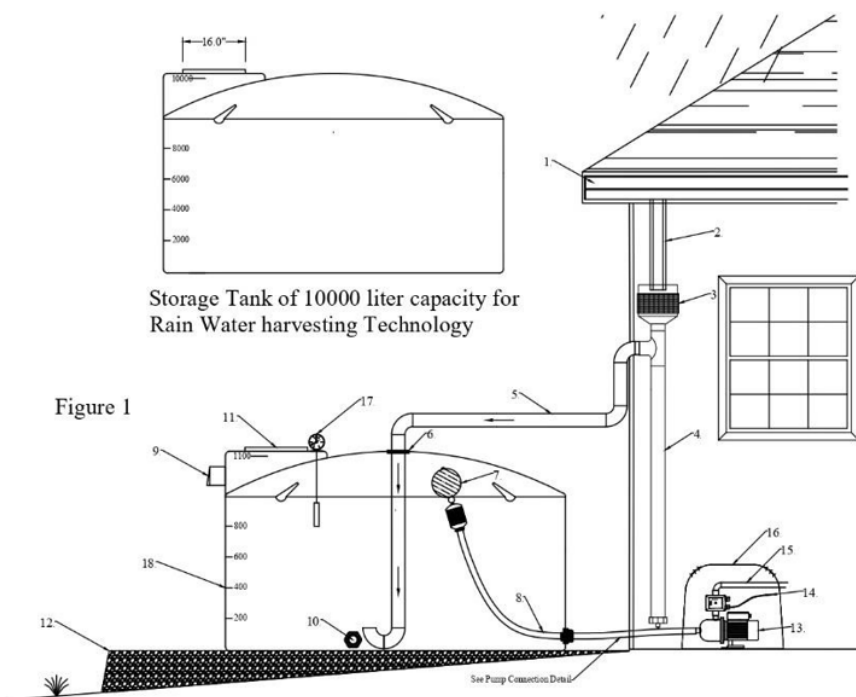


Figure 4: Option 1: Using rainwater harvesting technology directly to fulfill domestic water demand (As a storage)

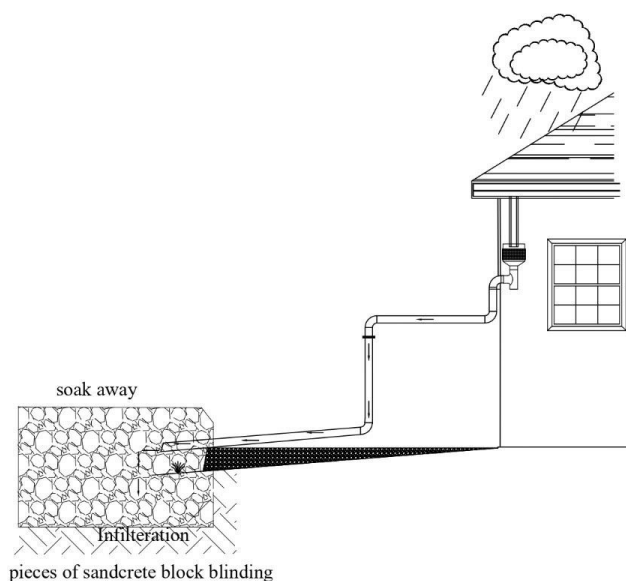


Figure 5: Option 2: Using rainwater harvesting technology as a ground water recharge method to increase ground water table

Table 2: Designing Storage Tank for Individual Household

Area	Average No person in household	Water requirement per day	Water accumulated per month	Tank capacity Required per House
Kathmandu	7	770	3450 liter	Min.8000 liter
Pokhara	5	550	3845 liter	Min.10,000liter
Lalitpur	5	550	3757 liter	Min 10,000 liter
Bharatpur	5	550	4053 liter	Min10,000 liter

Benefits of Rainwater Harvesting Technology

Rainwater harvesting technology has several benefits for communities and individuals, particularly in areas where water resources are scarce or unreliable. Rainwater

harvesting technology has the potential to provide numerous benefits to communities and individuals, particularly in areas where water resources are scarce or unreliable.

Table 3: Showing the Potential Demand of Kathmandu, Pokhara, Lalitpur and Bharatpur can be Fulfilled by Rainwater Harvesting Technology

Area:-Kathmandu	
Average Rainfall (mm/hrs.)	0.078
Quantity of water collected from single household (MLY)	0.042
Population (Numbers)	2933523
Average no of household (H.H)	437,354
Domestic water demand (DWD-LPD)	100
Total domesttic water Demand (TDWD) (MLY)	117780.94
Quantity of water collected from total household (MLY)	18090.79
Potential Demand Full filled by the (RWH/DWD)	0.155

If Every House of Kathmandu will be equipped with the rainwater harvesting Technology, simply it can fulfill nearly about 15.5% of total domestic demand of water annually.

Area:-Pokhara	
Average Rainfall (mm/hrs.)	0.087
Quantity of water collected from single household (MLY)	0.0461
Population (Numbers)	5,18,452
Average no of household (H.H)	101,699
Domestic water demand (DWD-LPD)	110
Total domesttic water Demand (TDWD) (MLY)	20815.8478
Quantity of water collected from total household (MLY)	4692.0844
Potential Demand Full filled by the (RWH/DWD)	0.2254

If Every House of Pokhara will be equipped with the rainwater harvesting Technology, simply it can fulfill nearly about 22.54% of total domestic demand of water.

Area:-Lalitpur	
Average Rainfall (mm/hrs.)	0.085
Quantity of water collected from single household (MLY)	0.045
Population (Numbers)	468132
Average no of household (H.H)	97,394
Domestic water demand (DWD-LPD)	110
Total domesttic water Demand (TDWD) (MLY)	18795.4998
Quantity of water collected from total household (MLY)	4390.17
Potential Demand Full filled by the (RWH/DWD)	0.233

If Every House of Lalitpur will be equipped with the rainwater harvesting technology, simply it can fulfill nearly about 23.35% of total domestic demand of water.

Area:-Bharatpur	
Average Rainfall (mm/hrs.)	0.093
Quantity of water collected from single household (MLY)	0.0486
Population (Numbers)	369377
Average no of household (H.H)	77,838
Domestic water demand (DWD-LPD)	110
Total domesttic water Demand (TDWD) (MLY)	14830.49
Quantity of water collected from total household (MLY)	3786.2
Potential Demand Full filled by the (RWH/DWD)	0.255

If Every House of Bharatpur will be equipped with the rainwater harvesting Technology, simply it can fulfill nearly about 25.5% of domestic demand of water.

Overall, rainwater harvesting technology can help to fulfill water demands by providing a reliable and sustainable source of water for households and communities. By reducing reliance on municipal water supplies, conserving water resources, and promoting sustainable water management practices, rainwater harvesting can help to ensure that water needs are met now and in the future.

Problems of Rainwater Harvesting Technology

Rainwater harvesting technology can provide a sustainable source of water for households and communities, there are potential challenges and limitations that need to be considered when implementing these systems. Limitation of water availability due to variation in precipitation patterns, water quality issues, maintenance requirement to ensure the collection, storage and distribution system, installation cost and legal issue are some of the problems regarding the rainwater harvesting technology.

Law, Policy and Strategy

The Inter-governmental Panel on Climate Change (IPCC) has listed rainwater-harvesting as a key strategy for a planned adaptation in the water sector. Most related policies, strategies and legislations are pre- climate change providing no significant value for the formulation of specific climate change adaptation strategies and that there is no mechanism to coordinate actions for the policy statements about rainwater- harvesting that are found strewn in almost all policy and strategy documents. There is no mechanism to coordinate actions for the policy statements about rainwater-harvesting that are found strewn in almost all policy and strategy documents. There is no mechanism to coordinate actions for the policy statements about rainwater-harvesting that are found strewn in almost all policy and strategy documents. For a more effective adaptation to climate change, based on rainwater harvesting, actions are suggested to mainstream rainwater harvesting-based adaptation into development; to design adaptation as a phased process; integrate mitigation and adaptation; put in place effective systems for assessment and mapping of vulnerability; avoid maladaptation; establish the centrality of disaster risk management in the institutional setup for rainwater harvesting-based climate change adaptation.

In Nepal, the law, policy, and strategy related to rainwater harvesting are mainly aimed at promoting sustainable use of water resources, increasing access to safe drinking water, and reducing water scarcity. National Water Supply and Sanitation Policy 2006, recognizes rainwater harvesting as sustainable and cost- effective means of providing safe drinking water and also National Drinking Water Quality Standards 2007, provide guidelines for the design and construction of rainwater harvesting system. Local Level Drinking Water and Sanitation Master Plan 2016, outlined strategies and action plan promotion of rainwater harvesting systems and provides guidelines for their design and construction. There are also several I/ NGOs and government agencies promoting rainwater

harvesting. Although, important of rainwater harvesting was highlighted for a long time, appropriate strategy and action planning has not been seen on action at often. Therefore, promotion of rainwater harvesting in Nepal is an important strategy for ensuring sustainable water management and improving access to safe drinking water.

CONCLUSION

Rainwater harvesting technology has the potential to provide numerous benefits to communities and individuals, particularly in areas where water resources are scarce or unreliable. Climate change impact on the water security and impact the temperature and precipitation patterns, rainwater harvesting technology has the potential to provide numerous benefits to communities and individuals, particularly in areas where water resources are scarce or unreliable. Promotion of rainwater harvesting in Nepal is an important strategy for ensuring sustainable water management and improving access to safe drinking water, especially in rural areas. The laws, policies, and strategies outlined above provide a framework for the implementation of rainwater harvesting initiatives at the national and local levels in Nepal.

From the analysis and through our research work it is found that if we can simply install and construct rainwater harvesting technology in our individual household only. It nearly fulfills about 15-25% of our domestic water demand. As in urban and rural area of Nepal still nearly about 50% of water demand is fulfilled by groundwater source which increase to 60-70% in dry season. If we can implement the rainwater harvesting technology it will also help to excessive extraction of ground water. In near future due to rapid population growth, urbanization and climate change, demand of water is going to be excessively increased which ultimately create the water scarcity. So our concern authority and local government should identify rain water harvesting technology as essential part for the ground water recharge and for water resources conservation. Every metropolitan city, municipality and rural municipality should make guidelines and standards for rainwater harvesting technology. They have to make a mandatory bye law for the compulsory construction and installation of RWH technology to get a building completion certificate for newly constructed buildings as well existing building also. Local government should start to increase ground water infiltration rather than the surface runoff by reducing the ground coverage percentage and promoting rain water harvesting concept.

LIMITATIONS

- As the design study analyze only single household domestic demand of rainwater harvesting, entire rainfall harvest is not covered.
- The study area is vast and more research time is required.
- Lack of availability of data and document related to the study.
- Financial Aspect is also one of the limitation of the study.

Acknowledgement

We would like to thank our professors and friends who provided insight and expertise that greatly assisted the research. Also like to thank them for the comments that greatly improved the manuscript.

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